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TECHNICAL NOTE

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THE SOUTHERN SKY SURVEY PAYLOAD

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SUMMARY

Four Skylark rockets were fired from Woomera Missile Range, Australia, to measure stellar fluxes and nebulosities at energy bands between 1050 and 2800A. The payloads contained two basic types of detector systems: photomultipliers for the spectral region between 1900 and 2800A, and ionization chambers for the 1050 to 1500A range. Data acquisition was optimized by a spin control gas jet system. Also described are the vehicle, field operations, and performance.

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INTRODUCTION

During the past several years a number of measurements have been made from rockets of the ultraviolet fluxes of stars and nebulosities visible in the northern hemisphere. The presence in southern skies of features such as the Magellanic Clouds and the more pronounced structure of the Milky Way suggested that such flux measurements might profitably be extended into the southern hemisphere. Accordingly, four identical payloads were constructed to be flown in Australia from the Woomera range, using the British-manufactured Skylark rocket.

Each payload contained ten telescopes: six with electron multiplier phototube detectors filtered for sensitivity to energy bands at 2600 and 2100A; and four with ionization chamber detectors, two per telescope, responsive to selected energy ranges between 1050 and 1500A. Since the scanning of the sky was determined by the motion of the rocket, a spin control system was used to optimize data acquisition.

VEHICLE

Skylark is a high altitude research rocket (Reference 1) — see Figure 1 — designed to carry a payload of 250 pounds to altitudes up to 100 miles when used as a single-stage vehicle and to 140 miles when boosted. It is powered by the Raven solid propellant motor and is dart-stabilized by three fixed fins; it has no other form of control.

The Raven II motor with Cuckoo booster selected for these firings performs as illustrated in Figures 2 and 3. The motor burns for about 40 seconds and provides a thrust of 12,000 pounds. Its longitudinal acceleration is less than 10g, and the fin-induced roll is less than 0.5 rps in either direction. The diameter of the motor is 17 inches, and its length is 17 feet 2 inches. A quick-release manacle ring clamps the payload to the motor assembly.
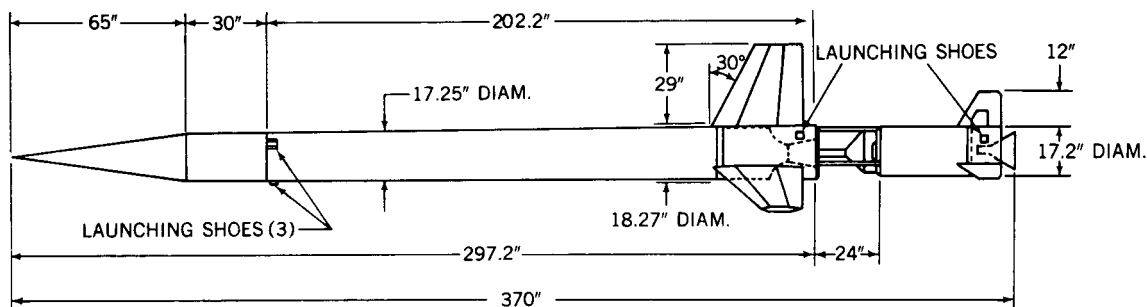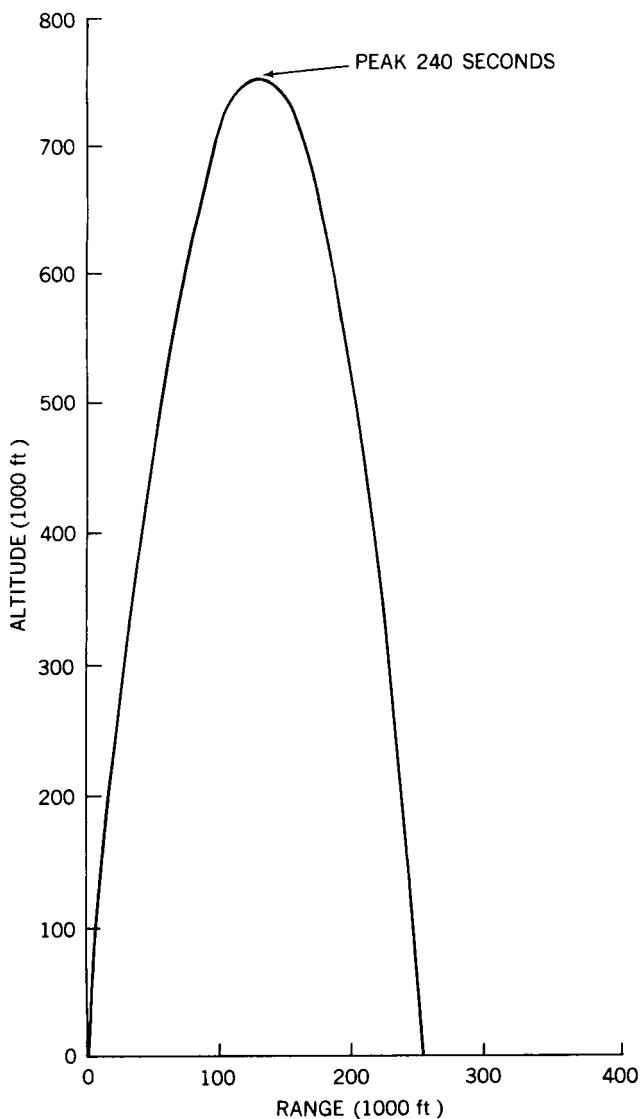
Figure 1—The Skylark rocket with Cuckoo booster.

Figure 2—Skylark trajectory using Raven II motor and Cuckoo booster.

PAYLOAD STRUCTURE

The payload (Figure 4) consisted of an unpressurized cylindrical section containing the telescopes and a pressurized nose ogive containing support instrumentation. The structural member in the unpressurized section was a hexagonal magnesium casting with mounting and access holes in each face. The telescopes were mounted in alternate faces 120 degrees apart. One face supported two photomultiplier and two ion chamber telescopes, and the other two faces each supported two photomultiplier telescopes and one ion chamber telescope. All mounting holes on all four rockets and the mounting flanges on all the telescopes had accurately machined surfaces so that the telescopes could be completely interchangeable and still maintain the
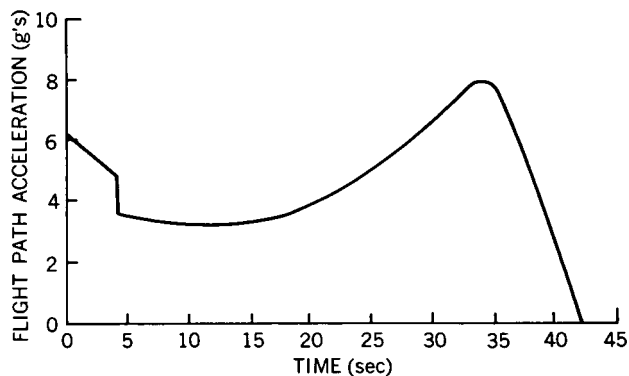

Figure 3—Skylark acceleration profile: Raven II motor and Cuckoo booster.

angular relation between optical axes to within ± 3 minutes of arc. Three 120-degree panels were fitted around the casting to provide an a e r o d y n a m i c fairing during boost. In addition, the panels protected the telescopes from contamination on the ground and in early flight, and permitted an in-flight dark calibration of the telescope systems. These spring-loaded panels were held on at top and bottom by two steel straps. Squib-powered pin pullers separated the straps 70 seconds after takeoff and permitted the panels to eject. At the base of the magnesium casting were mounted amplifiers, high voltage supplies, and battery packs directly associated with the telescopes. Two 48-pin umbilical connectors were also located at this position.

In the nose ogive, the support instrumentation was mounted on aluminum plates suspended between four longitudinally stressed steel rods. A tripod mount above the top plate supported two magnetometers as far away from other instrumentation as possible. An ogive was chosen instead of the standard Skylark right-cone nose not only to provide more usable volume but also to furnish a nearly cylindrical section near the base of the nose on which a quadraloop telemetry antenna could be mounted.

TELESCOPES

The photomultiplier telescope (Figures 5 and 6) was a 6-inch f/3.5 Cassegrainian system with a paraboloidal primary and a spherical secondary, and a 2-degree field of view. The secondary was ground to a sphere instead of the more conventional hyperboloid in order to degrade the image quality. Image quality was not a primary factor, provided all the incident flux from a star within

MAGNETOMETERS

PRESSURE BOTTLE

SUPPORT INSTRUMENTATION

DKT-7 TRANSMITTER

PHOTOMULTIPLIER TELESCOPE

ION CHAMBER TELESCOPE

TELESCOPE SECTION

BUTTING CONNECTOR (one of two)

MANACLE RING

Figure 4—S o u t h e r n Sky Survey payload. Nose ogive and skin panels are removed; p r o t e c t i v e dust covers are mounted over telescope apertures.

the field reached the cathode of the photomultiplier. However, a perfectly imaging system would impose a square wave input on the amplifier, producing overshoot and a tendency to cathode fatigue with the logarithmic circuitry used. Therefore the image quality was intentionally reduced so that the shapes of the leading and trailing edges of the light pulse would approximate the shape of the amplifier response curve. A two-element quartz field lens in the focal plane imaged the primary mirror on the photocathode to eliminate nonuniformities in cathode response. The detectors for these telescopes were EMI 6256N photomultipliers. The Sweet type logarithmic amplifier circuit
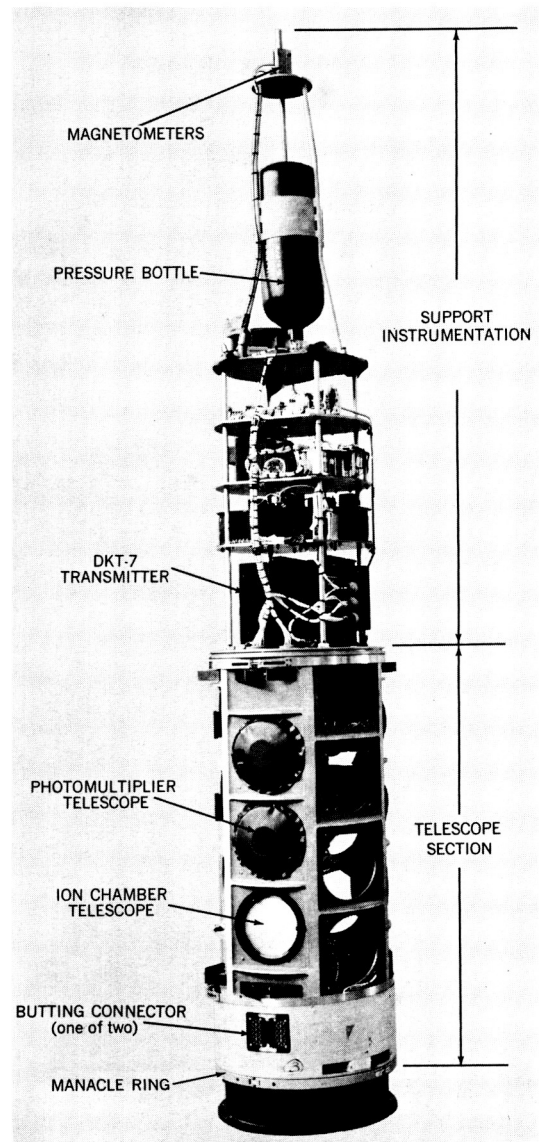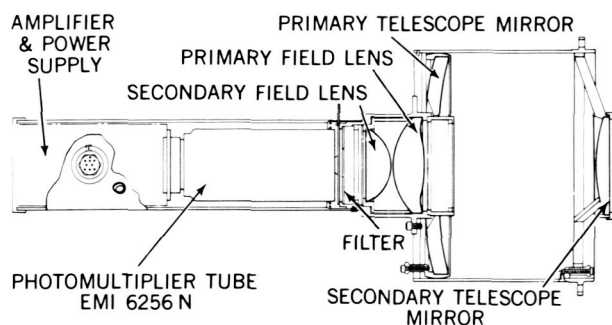
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Figure 5—Photomultiplier telescope assembly.

Figure 6—Photomultiplier telescope. The detector-amplifier assembly is shown removed from its pressurized housing.

(Reference 2) was modified* for use at the required low energy levels. Each photomultiplier, with its amplifier and high voltage supply, was mounted in a pressurized housing to eliminate corona during depressurization of the rocket. As a result, each telescope-detector assembly was an integrated unit interchangeable with other units. This interchangeability considerably reduced field maintenance problems.

A filter was mounted in each telescope to provide spectral discrimination. Two types of filters were used. The first was a crystal and glass sandwich (Reference 3) with a 180A bandpass centered at 2600A (Figure 7). The mount for this filter was directly in front of the photomultiplier, where the light formed an f/1 converging beam approximately 1 inch in diameter. The second type of filter was an interference filter peaking at 2100A (Figure 8). In order to avoid the highly convergent beam between the photomultiplier and field lens, this filter was made 2 inches in diameter and was mounted in front of the field lens. In this f/3.5 beam the filter had an effective bandwidth of 230A. The *spectral* sensitivity of each telescope unit was computed from the measured transmission curves of the filter and field lenses and from the measured spectral sensitivity of the photocathode. A relative calibration curve of each photomultiplier-amplifier system was obtained by comparison with a reference photomultiplier and linear amplifier. The *absolute* sensitivity of the assembled telescope was measured at 2537A with a standard mercury arc source. This measurement was made at three distances to check the shape of the relative calibration curve. A secondary standard lamp was carried to the field, and the inverse square law calibration was repeated a few days before flight as a final check.

The six photomultiplier telescopes in each rocket were mounted in pairs having parallel optical axes. One telescope of a pair contained
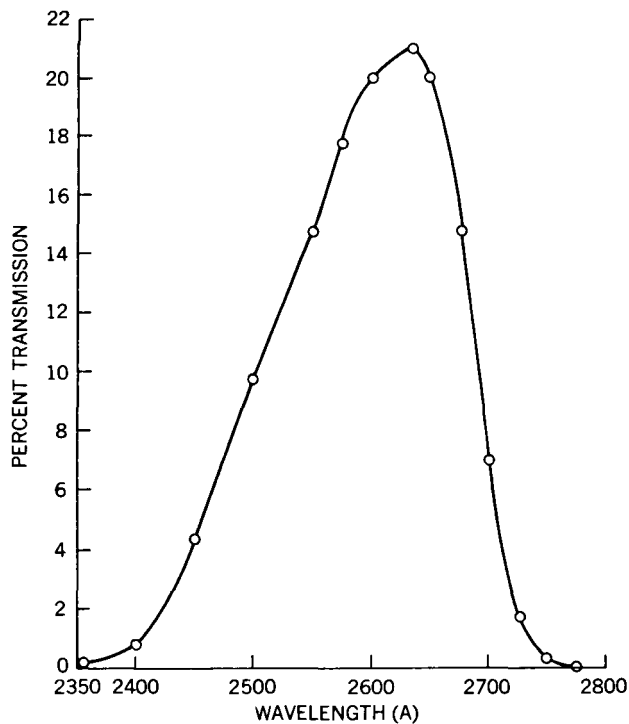
Figure 7—Transmission of 2600A filter.

Figure 8—Transmission of 2100A filter.

a 2600A filter, while the other contained a 2100A filter; this permitted simultaneous two-color observations of stars at these wavelengths.

Each ion chamber telescope (Figures 9 and 10) consisted of a 6-inch spherical mirror with two ion chambers mounted on the focal surface. The ion chambers had 2-degree fields of view and were mounted in the roll plane of the rocket so that a star would be seen first by one chamber and then by the other as the rocket spun. The mirror was aluminum-coated with an overcoat of magnesium fluoride to enhance the reflectance in the vacuum ultraviolet (Reference 4). The mirror was mounted in the rocket so that it looked across the rocket diameter. A 6.25-inch hole on the opposite side of the rocket casting provided an entrance stop to improve the off-axis imagery of the spherical mirror. The combined vignetting from the stop and the ion chamber support brackets was essentially
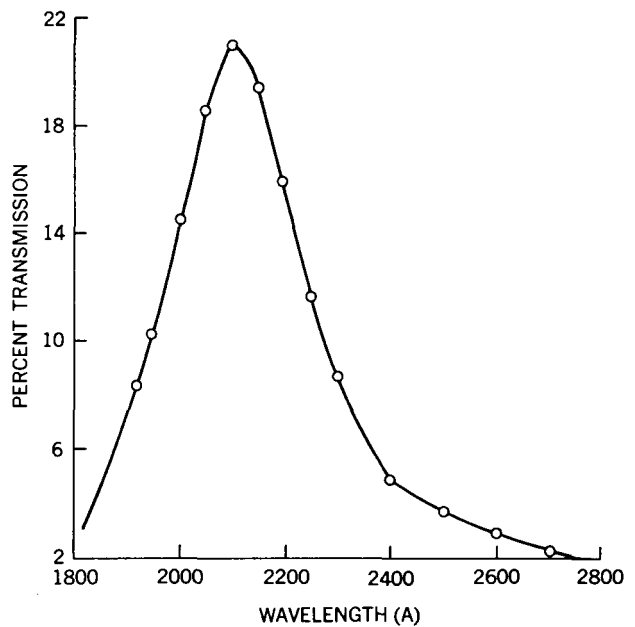

Figure 9—Ion chamber telescope assembly.
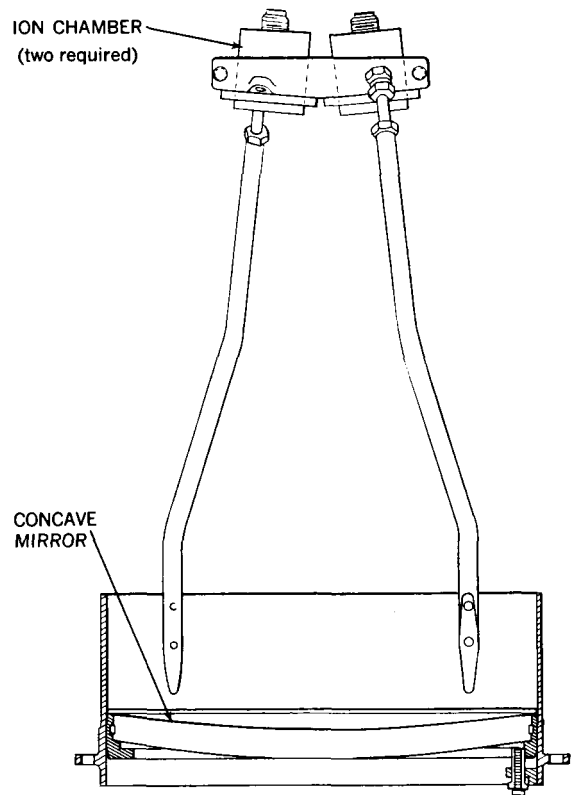
constant over the 2-degree field of each detector. The measured effective aperture of the system was 4.8 inches.

The ion chambers used were the ceramic type developed at the Goddard Space Flight Center (Reference 5); see Figure 11. The fill gases, window materials, and resulting spectral sensitivities are summarized in Table 1. The ionization efficiency of nitric oxide at Lyman-α (Reference 6) was used as the fundamental calibration standard. The calibration was extended

Figure 10—Ion chamber telescope.

Figure 11—Ceramic ion chamber.

to other wavelengths by means of a sodium salicylated photomultiplier, which is assumed to have a uniform response over this wavelength region. The spectral response curve of each flight chamber was determined by comparison with the sodium salicylated multiplier. Each ion chamber had a linear electrometer amplifier of the type developed by Praglin and Nichols (Reference 7) with a sensitivity of 10^{-12} ampere per telemetered volt. The system sensitivity was adjusted to the desired value by varying the negative high voltage on the ion chamber and thus changing the gas gain of the detector. The overall sensitivity was computed from the effective aperture and reflectance of the mirror, together with the quantum efficiency and operating gain of the ion chamber.

It was not practical to carry a vacuum monochromator into the field to check ion chamber calibrations before flight. As an alternative, a small fixture was built to hold an ion chamber a fixed

Table 1

Spectral Responses of Flight Ion Chambers.

Gas	Gas Cutoff (A)	Window Cutoff (A)	Window Material
Ethylene oxide	1150	1050	Lithium fluoride
Nitric oxide	1350	1225	Calcium fluoride
Carbon disulfide	1240	1050	Lithium fluoride
Acetone	1280	1225	Calcium fluoride
Ethyl sulfide*	1500	1350	Barium fluoride

*These chambers had just been developed in an attempt to extend the spectral range beyond 1350A. They were found to have a very short shelf life. After one month in the field, all had deteriorated to a point where they were no longer usable. Only one of this type of chamber was flown, and that was in the first rocket.

distance from a hydrogen lamp while the intervening path was flushed with nitrogen. Immediately after calibration in the laboratory, each ion chamber was placed in this fixture to record an output current. In the field, this procedure was repeated before flight to determine whether the chamber sensitivity had significantly changed. While this technique was not as satisfactory as a laboratory calibration, sensitivity changes greater than 15 percent could be detected. No changes of this magnitude were found in any but the ethyl sulfide chambers (see footnote to Table 1). Unlike the photomultipliers, the ion chamber telescopes could not remain pressurized throughout flight. Therefore, high voltage was not applied to the chamber shells until 70 seconds after takeoff, when the telescope volume had evacuated enough to prevent corona.

SUPPORT INSTRUMENTATION

To obtain a reliable measurement of stellar flux levels, it was desirable that a star remain in the 2-degree field of view of each telescope for at least 0.1 second, corresponding to a spin rate of 0.05 rps. Because of manufacturing tolerances in the fins, the Skylark may achieve spin rates as high as 0.5 rps. Accordingly a spin control device capable of sensing both magnitude and direction of spin and adjusting the rate to the desired value was necessary. A nitrogen bottle was placed in the nose with parallel plumbing leading to two opposed pairs of roll jets, each with its own normally closed valve, mounted near the rocket's center of gravity. A rate gyro sensed the rate and direction of spin and controlled a relay system (Figure 12) that established an electrical path to the appropriate valve. This valve was opened by the timer 78 seconds after takeoff. When the preset rate was achieved, the rate gyro closed a normally open valve in the line to stop the spin control action. A pressure gauge monitored the line pressure aft of the normally open valve. When spin control action was requested, there was a drop in the line pressure; and, at completion, the pressure dropped to zero – giving positive indication of the operation of the spin control system.

The remaining nose instrumentation consisted of two Schoenstedt RAM-3 magnetometers (one parallel and one perpendicular to the rocket axis) for preliminary aspect information, an accelerometer
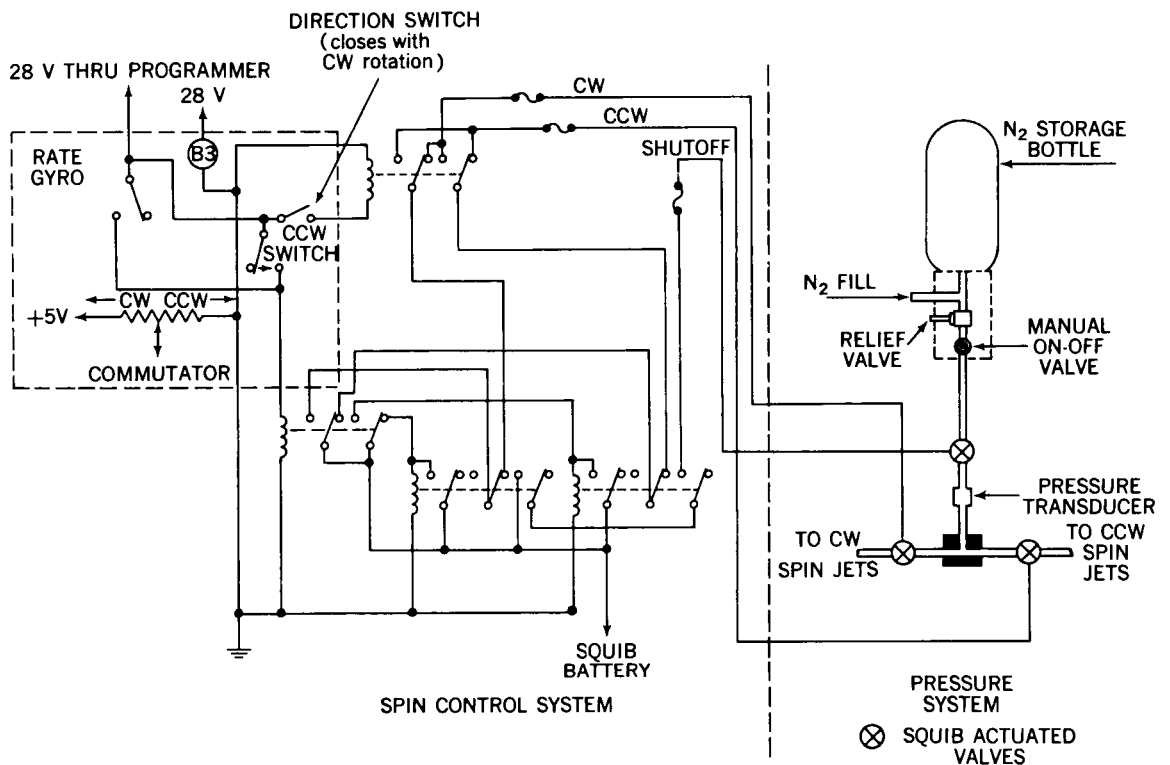
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Figure 12—Spin control logic and pressure system.

to monitor rocket performance during boost, battery packs, and the telemeter transmitter. A motor-driven timer switched a full time telemeter channel from the accelerometer to telescope data after burnout, turned on ion chamber high voltage, ejected skin panels, and initiated the spin control system.

The PPM DKT-7 transmitter was used for these flights. The standard DKT-7 calibrator was modified to provide a voltage calibration of each channel once every 60 seconds. Fourteen of the channels were used for the six photomultipliers and eight ion chambers, and the fifteenth channel was subcommutated to preset magnetometer data and to preset monitors of power supplies, spin control system, and door ejection. A telemetry receiving van was equipped in the United States and shipped to Australia for these firings.

Pre-flight checkout of each rocket was accomplished with an external control console (Figure 13). This console permitted rocket checkout on either external or internal power, independent operation of each rocket subsystem, and read-out of each data channel on the panel meter. A *stop action* button was installed on the panel to interrupt the firing circuits in case of a last minute malfunction; fortunately this button was never used. The control console was connected to the rocket through land lines terminating in two 48-pin connectors at the base of the payload. Disconnect occurred 15 seconds before firing. In addition, a 4-pin "snatch plug" was attached to the rocket and pulled out by a lanyard at takeoff. When this plug was pulled, shorts were removed from the pyrotechnic devices, the timer was started, and all rocket systems were turned on — regardless of the condition of the control panel at disconnect.
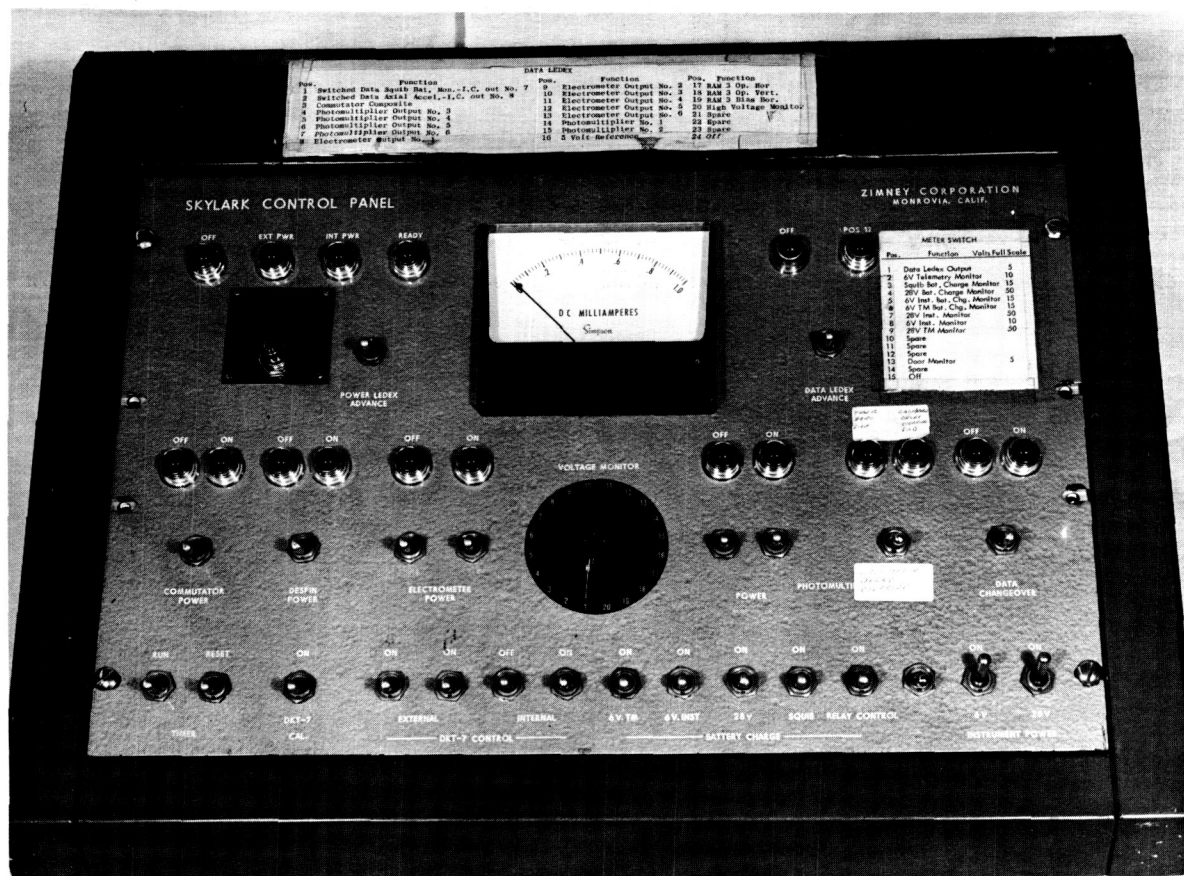
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Figure 13—Skylark control panel.

FIELD OPERATIONS

The rocket preparation was done at the Weapons Research Establishment (WRE) in Salisbury, about 20 miles north of Adelaide, South Australia. The Aerodynamics Division of WRE provided a test area 25 by 40 feet with work benches and 220 volt, 50 cycle power; a machine shop and parts stores were made available.

At Salisbury each subsystem was checked out, and a full simulated flight check was performed with all systems functioning, but with a set of non-flight telescopes. Then a selected set of flight photomultiplier telescopes was installed and checked for performance in the payload. Finally, the payload and all the equipment necessary for testing, checkout, and the actual firing was packed for shipment to the Woomera missile range. For the first firing, personnel and equipment were transported to Woomera via a commercial airline under contract to provide shuttle service between Adelaide and Woomera. However, transportation procedures required that shipments of this size be released to the shipper at least 10 days prior to expected delivery at Woomera. After the first firing this delay was reduced to 1 day by sending the equipment via truck, with the personnel following via air.

The missile ranges operated by WRE are based at Woomera, some 300 miles northwest of Adelaide. (The town of Woomera — population about 4000 — is located 5 miles from Pimba, on the Trans-Australian railway, and is served by a spur line. The country is semidesert with a mean rainfall of about 7 inches per year.) A number of ranges are used at Woomera for special purposes. The principal missile range, however, is based at Koolymilka, about 25 miles from town. It provides a number of independent launching aprons, so that work can proceed on several projects at the same time. A range of approximately 1250 miles over practically uninhabited land is available. A "Homestead Warning System" has been developed to control stock and other movements in the range areas during trial periods.

At the range a test shop is available for the test and checkout of Skylark payloads. Here the payload was checked for damage in transit. Final settings were made for all detector sensitivities and amplifier zeros, and high voltage levels were set for the ion chambers. All flight chambers were then installed in the payload, high voltage leads were soldered to the copper fill stems, and the stems were completely epoxied to prevent corona from the stem to the signal ground shell less than 2 mm away.

A final pre-tower checkout was held with all systems complete and functioning: All detectors were activated, all channels were positively identified, every de-spin situation was simulated by vertical suspension of the payload from the ceiling, door blowoffs were simulated, and all monitor voltages were checked. All telescope protective covers and tapes were removed, and the skin farings were placed in position for the final time. The payload was then transported by truck to the Skylark launching pad for erection into the tower.

The tower is a 100-foot open structure made up primarily of three army Bailey bridges. Depending on whether or not a booster is used, two different working levels are provided. A removable rail permits access to the payload. Attached to the launcher is a pneumatically operated system for extracting the umbilical connectors. The land lines run from these connectors to the Equipment Center some 500 feet away.

Upon arrival at the launcher, the payload was hoisted to the appropriate level and mounted in the firing position on a temporary plate set between the rails. The final pre-flight check was then made. After this check the payload was swung clear of the rails, and the launcher was released to the launcher officer for installation of the motor and booster. The motor was backed up to the tower base on a railed dolly, and the dolly was pivoted into the tower. The motor was then hoist-held about 10 feet up in the tower while its dolly was removed and a second dolly holding the booster was erected into the tower. (The booster dolly is part of the tower structure during launch.) The motor was lowered onto the booster, and mating was completed. Finally, the payload was swung back in line and permanently bolted to the forward skirt of the motor. A removable service plate at the forward end of the motor permits access for connection of the ignition lines. After the motor is placed in the tower, range safety regulations require that no voltage sources (i.e., ohmmeters) be on the tower and that no personnel remain on the tower after 8 hours of duty in any 24 hour period.

The Skylark launch procedure requires automatic programming of the firing sequence during the last 2 minutes of the countdown. If desired, the automatic sequencer is able to control the final 6

minutes. Prior to this, the count is conducted informally. For the NASA payloads the support instrumentation was turned on at T-6 minutes; but, in order to provide optimum zero settings, the detector amplifiers were turned on as early as T-45 minutes. At T-2 minutes the automatic sequencer took control to close firing lines, extract umbilicals, start the tracking cameras, and close the firing switch.

FLIGHT PERFORMANCE

Skylark 9.01 was fired at 1215UT on September 18, 1961. Two of the six photomultiplier telescopes performed perfectly throughout the flight. Corona in the photomultiplier high voltage circuitry of the remaining four units, implying a break in the pressure tightness of the units, caused full scale noise on the associated telemetry channels. The noise induced into the ion chamber amplifiers through the 28-volt supply line caused the latter to show off-scale readings during part of the flight. Compounding these difficulties, the *stop* spin control valve closed the pressure line before spin control action was called for. Thus, no spin control occurred and the missile attained a coasting spin of about 0.08 rps — still slow enough to obtain useful data. Finally the protective skin panels were late in ejecting, which was attributed to the mechanical assembly rather than to the electrical or pyrotechnical system.

Skylark 9.01 came in streamlined and, while the motor was found beside a hole in the desert, no part that could convincingly be identified as payload was ever found. In order to simplify post-flight analysis, the remaining payloads were modified to separate the instrument head from the Skylark body at 375 seconds so that the payload could be recovered and inspected. The de-spin control checkout procedure was modified to include a more rigorous checkout, and no further difficulty was experienced in controlling the spin of the final three Skylarks. Additional care was given the pressure-tight sealing of the photomultiplier telescope electronics to prevent corona. Finally, the bands holding the protective skin panels were eased in tension; it had been concluded that aerodynamic heating had increased the band tension so that the pin pullers could not operate.

Skylark 9.02 was fired at 1119UT on October 4, 1961. The photomultiplier detectors and associated circuitry performed satisfactorily throughout the flight. A few brief periods of saturation in the ion chamber amplifiers were attributed to interaction caused by the use of a single converter to supply all the ion chamber high voltages. Again, the skin panels ejected late and at different times. These factors, coupled with the recovery of a panel and adjacent pieces of the casting, led to the unmistakable conclusion that design calculations for heat expansion of the panels could not have been correct. Heating of the panels early in the flight had wedged them against the retaining limits of the casting and prevented them from being ejected. As the heat was dissipated differently around the missile, each panel sprung loose at different times. Fortunately, the last door was ejected by 140 seconds. A reduction in the length of the panels cured this problem for the remaining two Skylarks.

Skylark 9.03 was fired at 1756UT on November 1, 1961. Not a single multiplier telescope maintained pressure tightness through takeoff, and all high voltage units went into corona. In addition, the ion chamber data were seriously affected because of the electrical coupling previously described in 9.01.

NITRIC OXIDE ION CHAMBER

ACETONE ION CHAMBER

2100 A PHOTOMULTIPLIER

2600 A PHOTOMULTIPLIER
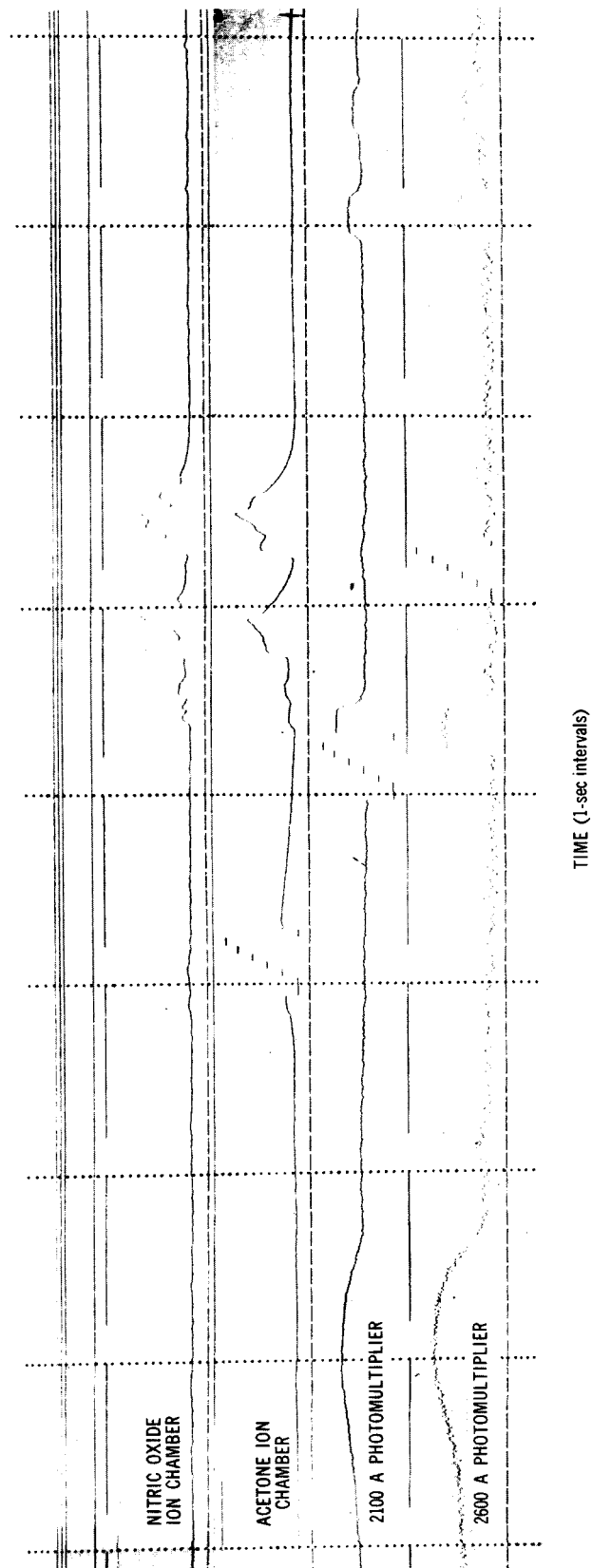
TIME (1-sec intervals)

Figure 14—Sample telemetry from Skylark 9.02. Channel identifications from top to bottom are: nitric oxide ion chamber, acetone ion chamber, 2100A photomultiplier, and 2600A photomultiplier. The extended source to the left on the photomultiplier channels is night airglow. All other signals are stellar. Vertical timing marks represent 1-second intervals.

In spite of the success of the multiplier telescopes in 9.02, it was now apparent that the mechanical design involving their pressure tightness was basically faulty. A complete redesign at this stage of the firings was out of the question. Because of this and because the ion chamber data were considered more important, the last payload was converted to an all-ion-chamber experiment with only two multiplier telescopes retained to yield rocket attitude. The two multiplier units were epoxy-flooded in order to improve pressure tightness.

Skylark 9.04 was fired at 1804UT on November 20, 1961. The multiplier telescopes performed perfectly, and the ion chambers yielded good data from both stars and extended sources. There were still some brief periods of ion chamber amplifier saturation; the cause is not yet determined.

CONCLUSIONS

A telemetry sample from 9.02 is shown in Figure 14. These data are now in the process of being reduced. It is already evident that the project produced a great deal of significant data. The data received by the photomultipliers in the 2100 and 2600A bands and the nitric oxide ion chamber in the 1300A band will be of great value in supplementing existing information from the northern hemisphere at similar wavelengths. In addition, data on stellar fluxes in the 1225 to 1280A region were obtained with the acetone ion chambers; and weak stellar signals were recorded at wavelengths below Lyman-α.

ACKNOWLEDGMENTS

REFERENCES

1. Dorling, E. B., "The First Six Skylark Firings," Royal Aircraft Establishment, Farnborough, England, Technical Note No. G.W. 530, October 1959.

2. Sweet, M. H., "Logarithmic Photometer," *Electronics* 19:105-109, November 1946.

3. Childs, C. B., "Broad-Band Ultraviolet Filters," *J. Opt. Soc. Amer.* 51(8):895-897, August 1961.

4. Hass, G., and Tousey, R., "Reflecting Coatings for the Extreme Ultraviolet," *J. Opt. Soc. Amer.* 49(6):593-602, June 1959.

5. Stober, A. K., "Ceramic Vacuum Ultraviolet Ion Chambers," NASA Technical Note D-1180, March 1962.

6. Watanabe, K., "Photoionization and Total Absorption Cross Section of Gases. I – Ionization Potentials of Several Molecules. Cross Sections of NH_3 and NO," *J. Chem. Phys.* 22(9):1564-1570, September 1954.

7. Praglin, J., and Nichols, W. A., "High-Speed Electrometers for Rocket and Satellite Experiments," *Proc. I.R.E.* 48(4):771-779, April 1960.